

WHAT IS CLAIMED IS:

1. A display image enhancement apparatus for use in generating additional pixel data from input image data, wherein a window of input pixel data is used to generate data for an additional pixel to be placed substantially in the center of the window, the display image enhancement apparatus comprising:

memory elements capable of receiving a chain of input pixel data and storing at least the window of input pixel data, the window of input pixels including a plurality of pixel pairs each of which respectively represents an angle of correlation;

instant angle detection circuitry capable of receiving the input pixel data stored in the memory elements and determining an instant angle having the highest correlation based on differential values of at least some of the pixel pairs, wherein a differential value is the difference between the values of pixels in a pixel pair;

substantial angle detection circuitry capable of determining a substantial angle having the highest correlation based on filtered differential values of at least some of the pixel pairs;

angle confirmation circuitry capable of determining an interpolation angle based on the instant angle and the substantial angle; and

an interpolator capable of determining the value of the additional pixel based on the values of pixels in the pixel pair corresponding to the interpolation angle.

2. The display image enhancement apparatus according to claim 1, further comprising a regional measurement circuitry capable of determining a general image pattern within the window of pixel data stored in the memory elements,

wherein the angle confirmation circuitry is capable of determining the interpolation angle based on the instant angle, the substantial angle, and the general image pattern.

3. The display image enhancement apparatus according to claim 2, wherein if the regional measurement circuitry detects an alphabet or numerical character, the angle confirmation circuitry generates 90° as the interpolation angle.

4. The display image enhancement apparatus according to claim 1, wherein if the instant angle and substantial angle are substantially equal to each other, the angle confirmation circuitry generates as the interpolation angle one of the instant angle, the substantial angle, and the average of instant angle and substantial angle.

5. The display image enhancement apparatus according to claim 1, wherein if the instant angle is substantially different from the substantial angle, the angle confirmation circuitry generates as the interpolation angle either the substantial angle or the weighted average of the instant angle and the substantial angle with the substantial angle given more weight.

6. The display image enhancement apparatus according to claim 1, further comprising a low pass filter capable of filtering the interpolation angle and generating a filtered interpolation angle,

wherein the interpolator is capable of determining the value of the additional pixel based on the values of pixels in the pixel pair corresponding to the filtered interpolation angle.

7. The display image enhancement apparatus according to claim 1, wherein the instant angle detection circuitry includes:

a differential calculator capable of calculating differential values of at least some of the pixel pairs in the window based on the pixel data stored in the memory elements.

8. The display image enhancement apparatus according to claim 7, wherein the instant angle detection circuitry further includes:

a lowest valley search circuit capable of determining the pixel pair in the window of pixels with the lowest differential value; and

angle finding circuitry capable of determining an angle corresponding to the pixel pair with the lowest differential value and generating the determined angle as the instant angle.

9. The display image enhancement apparatus according to claim 7, wherein the window of pixels includes a plurality of regions, and the instant angle detection circuitry further includes:

a global region detector capable of selecting a representative pixel pair from each of the regions, determining the representative pixel pair having the lowest differential value among the representative pixels, and selecting the region represented by the representative pixel pair with the lowest differential value;

a first valley detector capable of comparing the differential values of consecutive sets of immediately adjacent pixel pairs within the selected region and determining a pixel pair having a differential value that is smaller than the differential values of available immediately adjacent pixel pairs to the left and to the right in the selected region;

angle finding circuitry capable of determining an angle corresponding to the pixel pair determined by the first valley detector;

an angle reliability detector capable of comparing the differential value of the pixel pair determined by the first valley detector and the differential value of the pixel pair representing a 90° correlation; and

angle adjustment circuitry capable of outputting 90° as the instant angle if the differential value of the pixel pair determined by the first valley detector is greater than or substantially the same as the differential value of the pixel pair representing the 90° correlation, and otherwise outputting the angle determined by the angle finding circuitry as the instant angle.

10. The display image enhancement apparatus according to claim 7, wherein the substantial angle detection circuitry includes:

a recursive filter capable of filtering the differential values of at least some of the pixel pairs in the window;

a lowest valley search circuit capable of determining the pixel pair in the window of pixels with the lowest filtered differential value; and

angle finding circuitry capable of determining an angle corresponding to the pixel pair with the lowest filtered differential value and generating the determined angle as the substantial angle.

11. The display image enhancement apparatus according to claim 7, wherein the window of pixels includes a plurality of regions, and the substantial angle detection circuitry includes:

a recursive filter capable of filtering the differential values of at least some of the pixel pairs in the window;

a global region detector capable of selecting a representative pixel pair from each of the regions, determining the representative pixel pair having the lowest filtered differential value among the representative pixel pairs, and selecting the region represented by the representative pixel pair with the lowest filtered differential value;

a first valley detector capable of comparing the filtered differential values of consecutive sets of immediately adjacent pixel pairs within the selected region and determining a pixel pair first found to have a filtered differential value that is smaller than the filtered differential values of available immediately adjacent pixel pairs to the left and to the right in the selected region;

angle finding circuitry capable of determining an angle corresponding to the pixel pair determined by the first valley detector;

an angle reliability detector capable of comparing the filtered differential value of the pixel pair determined by the first valley detector and the filtered differential value of the pixel pair representing a 90° correlation; and

angle adjustment circuitry capable of outputting 90° as the substantial angle if the filtered differential value of the pixel pair determined by the first valley detector is greater than or substantially the same as the filtered differential value of the pixel pair representing the 90° correlation, and otherwise outputting the angle determined by the angle finding circuitry as the substantial angle.

12. An display image enhancement apparatus for use in generating additional pixel data from input image data, wherein a window of input pixel data includes a plurality of regions and is used to generate data for an additional pixel to be placed substantially in the center of the window, the display image enhancement apparatus comprising:

memory elements capable of receiving a chain of input pixel data and storing at least the window of input pixel data, the window of input pixels including a plurality of pixel pairs each of which respectively represents an angle of correlation;

instant angle detection circuitry capable of receiving the pixel data stored in the memory elements and determining an instant angle having the highest correlation based on differential values of at least some of the pixel pairs, wherein a differential value is the difference between the values of pixels in a pixel pair and wherein the instant angle detection circuitry includes

a differential calculator capable of calculating differential values of at least some of the pixel pairs in the window,

a global region detector capable of selecting a representative pixel pair from each of the regions, determining the representative pixel pair having the lowest differential value among the representative pixel pairs, and selecting the region represented by the representative pixel pair with the lowest differential value,

a first valley detector capable of comparing the differential values of consecutive sets of immediately adjacent pixel pairs within the selected region and determining a pixel pair having a differential value that is smaller than the differential values of available immediately adjacent pixel pairs to the left and to the right in the selected region, and

angle finding circuitry capable of determining an angle corresponding to the pixel pair determined by the first valley detector as the instant angle; and

an interpolator capable of determining the value of the additional pixel based on the values of pixels in the pixel pair corresponding to the instant angle.

13. The display image enhancement apparatus of claim 12, wherein the instant angle detection circuitry further includes:

an angle reliability detector capable of comparing the differential value of the pixel pair determined by the first valley detector and the differential value of the pixel pair representing a 90° correlation; and

angle adjustment circuitry capable of outputting 90° as the instant angle if the differential value of the pixel pair determined by the first valley detector is greater than or substantially the same as the differential value of the pixel pair representing the 90° correlation, and otherwise outputting the angle determined by the angle finding circuitry as the instant angle.

14. An display image enhancement apparatus for use in generating additional pixel data from input image data, wherein a window of input pixel data is used to generate data for an additional pixel to be placed substantially in the center of the window, the display image enhancement apparatus comprising:

memory elements capable of receiving a chain of input pixel data and storing at least the window of input pixel data, the window of input pixels including a plurality of pixel pairs each of which respectively represents an angle of correlation;

a differential calculator capable of calculating a differential value of at least some of the pixel pairs in the window based on the input pixel data, wherein a differential value is the difference between the values of pixels in a pixel pair;

substantial angle detection circuitry capable of determining a substantial angle having the highest correlation based on filtered differential values of at least some of the pixel pairs, wherein the substantial angle detection circuitry includes a recursive filter capable of filtering the differential values of at least some of the pixel pairs in the window and outputting the filtered differential values; and

an interpolator capable of determining the value of the additional pixel based on the values of pixels in the pixel pair corresponding to the substantial angle.

15. The display image enhancement apparatus of claim 14, wherein the window includes a plurality of regions and the substantial angle detection circuitry further includes:

a global region detector capable of selecting a representative pixel pair from each of the regions, determining the representative pixel pair having the lowest filtered differential value among the representative pixel pairs, and selecting the region represented by the representative pixel pair with the lowest filtered differential value;

a first valley detector capable of comparing the filtered differential values of consecutive sets of immediately adjacent pixel pairs within the selected region and determining a pixel pair having a filtered differential value that is smaller than the filtered differential values of available immediately adjacent pixel pairs to the left and to the right in the selected region; and

angle finding circuitry capable of determining an angle corresponding to the pixel pair determined by the first valley detector and outputting the determined angle as the substantial angle.

16. The display image enhancement apparatus of claim 15, wherein the substantial angle detection circuitry further includes:

an angle reliability detector capable of comparing the filtered differential value of the pixel pair determined by the first valley detector and the filtered differential value of the pixel pair representing a 90° correlation; and

angle adjustment circuitry capable of outputting 90° as the substantial angle if the filtered differential value of the pixel pair determined by the first valley detector is greater than or substantially the same as the filtered differential value of the pixel pair representing the 90° correlation, and otherwise outputting the angle determined by the angle finding circuitry as the substantial angle.

17. A display image enhancement method for use in generating additional pixel data from input image data, wherein a window of input pixel data is used to generate data for an additional pixel to be placed substantially in the center of the window, the display image enhancement method comprising the steps of:

receiving a chain of input pixel data and storing at least the window of input pixel data in memory elements, the window of input pixels including a plurality of pixel pairs each of which respectively represents an angle of correlation;

determining differential values of at least some of the pixel pairs based on the input pixel data stored in the memory elements, wherein a differential value is the difference between the values of pixels in a pixel pair;

determining an instant angle having the highest correlation based on the differential values of at least some of the pixel pairs;

determining a substantial angle having the highest correlation based on filtered differential values of at least some of the pixel pairs;

determining an interpolation angle based on the instant angle and the substantial angle;  
and

determining the value of the additional pixel based on the values of pixels in the pixel pair corresponding to the interpolation angle.

18. The display image enhancement method according to claim 17, further comprising the step of determining a general image pattern within the window of pixel data stored in the memory elements,

wherein the interpolation angle is determined based on the instant angle, the substantial angle, and the general image pattern.

19. The display image enhancement method according to claim 18, wherein if the determined general pattern is an alphabet or numerical character, 90° is determined as the interpolation angle.

20. The display image enhancement method according to claim 17, wherein if the instant angle and substantial angle are substantially equal to each other, one of the instant angle, the substantial angle, and the average of instant angle and substantial angle is determined as the interpolation angle.

21. The display image enhancement method according to claim 17, wherein if the instant angle is substantially different from the substantial angle, either the substantial angle or the weighted average of the instant angle and the substantial angle with the substantial angle given more weight is determined as the interpolation angle.

22. The display image enhancement apparatus according to claim 17, further comprising the steps of filtering the interpolation angle with a low pass filter and generating a filtered interpolation angle,

wherein the value of the additional pixel is determined based on the values of pixels in the pixel pair corresponding to the filtered interpolation angle.

23. The display image enhancement method according to claim 17, wherein the step of determining the instant angle includes the steps of:

determining the pixel pair in the window of pixels with the lowest differential value;

and

determining an angle corresponding to the pixel pair with the lowest differential value and generating the determined angle as the instant angle.

24. The display image enhancement method according to claim 17, wherein the window of pixels includes a plurality of regions, and the step of determining the instant angle includes the steps of:

selecting a representative pixel pair from each of the regions;

determining the representative pixel pair having the lowest differential value among the representative pixels;

selecting the region represented by the representative pixel pair with the lowest differential value;

comparing the differential values of consecutive sets of immediately adjacent pixel pairs within the selected region and determining a first valley pixel pair, wherein the first valley pixel pair has a differential value that is smaller than the differential values of available immediately adjacent pixel pairs to the left and to the right in the selected region;

determining an angle corresponding to the first valley pixel pair;

comparing the differential value of the first valley pixel pair and the differential value of the pixel pair representing a 90° correlation; and

outputting 90° as the instant angle if the differential value of the first valley pixel pair is greater than or substantially the same as the differential value of the pixel pair representing the 90° correlation, and otherwise outputting the angle corresponding to the first valley pixel pair as the instant angle.

25. The display image enhancement method according to claim 17, wherein the step of determining the substantial angle includes the steps of:

filtering the differential values of at least some of the pixel pairs in the window using a recursive filter;

determining the pixel pair in the window of pixels with the lowest filtered differential value; and

determining an angle corresponding to the pixel pair with the lowest filtered differential value and generating the determined angle as the substantial angle.

26. The display image enhancement method according to claim 17, wherein the window of pixels includes a plurality of regions, and the step of determining the substantial angle includes the steps of:

filtering the differential values of at least some of the pixel pairs in the window using the recursive filter;

selecting a representative pixel pair from each of the regions;

determining the representative pixel pair having the lowest filtered differential value among the representative pixel pairs;

selecting the region represented by the representative pixel pair with the lowest filtered differential value;

comparing the filtered differential values of consecutive sets of immediately adjacent pixel pairs within the selected region and determining a first valley pixel pair, wherein the first valley pixel pair has a filtered differential value that is smaller than the filtered differential values of available immediately adjacent pixel pairs to the left and to the right in the selected region;

determining an angle corresponding to the first valley pixel pair;

comparing the filtered differential value of the first valley pixel pair and the filtered differential value of the pixel pair representing a  $90^\circ$  correlation; and

outputting  $90^\circ$  as the substantial angle if the filtered differential value of the first valley pixel pair is greater than or substantially the same as the filtered differential value of the pixel pair representing the  $90^\circ$  correlation, and otherwise outputting the angle corresponding to the first valley pixel pair as the substantial angle.

27. An display image enhancement method for use in generating additional pixel data from input image data, wherein a window of the pixel data includes a plurality of regions and is used to generate data for an additional pixel to be placed substantially in the center of the window, the display image enhancement method comprising the steps of:

receiving a chain of input pixel data and storing at least the window of input pixel data in memory elements, the window of input pixels including a plurality of pixel pairs each of which respectively represents an angle of correlation;

determining differential values of at least some of the pixel pairs in the window, wherein a differential value is the difference between the values of pixels in a pixel pair;

determining an instant angle having the highest correlation based on differential values of at least some of the pixel pairs, wherein the step of determining the instant angle includes

selecting a representative pixel pair from each of the regions,

determining the representative pixel pair having the lowest differential value among the representative pixel pairs,

selecting the region represented by the representative pixel pair with the lowest differential value,

comparing the differential values of consecutive sets of immediately adjacent pixel pairs within the selected region and determining a first valley pixel pair, wherein the first valley pixel pair has a differential value that is smaller than the differential values of available immediately adjacent pixel pairs to the left and to the right in the selected region, and

determining an angle corresponding to the first valley pixel pair as the instant angle; and

determining the value of the additional pixel based on the values of pixels in the pixel pair corresponding to the instant angle.

28. The display image enhancement method of claim 27, wherein the step of determining the instant angle further includes the steps of:

comparing the differential value of the first valley pixel pair and the differential value of the pixel pair representing a 90° correlation; and

outputting 90° as the instant angle if the differential value of the first valley pixel pair is greater than or substantially the same as the differential value of the pixel pair representing the 90° correlation, and otherwise outputting the angle corresponding to the first valley pixel pair as the instant angle.

29. An display image enhancement method for use in generating additional pixel data from input image data, wherein a window of the pixel data is used to generate data for an additional pixel to be placed substantially in the center of the window, the display image enhancement method comprising the steps of:

receiving a chain of input pixel data and storing at least the window of input pixel data in memory elements, the window of input pixels including a plurality of pixel pairs each of which respectively represents an angle of correlation;

calculating a differential value of at least some of the pixel pairs in the window based on the input pixel data stored in the memory elements, wherein a differential value is the difference between the values of pixels in a pixel pair;

determining a substantial angle having the highest correlation based on filtered differential values of at least some of the pixel pairs, wherein the step of determining the substantial angle includes filtering the differential values of at least some of the pixel pairs in the window using a recursive filter; and

determining the value of the additional pixel based on the values of pixels in the pixel pair corresponding to the substantial angle.

30. The display image enhancement method of claim 29, wherein the window includes a plurality of regions and the step of determining the substantial angle further includes the steps of:

selecting a representative pixel pair from each of the regions;

determining the representative pixel pair having the lowest filtered differential value among the representative pixel pairs;

selecting the region represented by the representative pixel pair with the lowest filtered differential value;

comparing the filtered differential values of consecutive sets of immediately adjacent pixel pairs within the selected region and determining a first valley pixel pair, wherein the first

valley pixel pair has a filtered differential value that is smaller than the filtered differential values of available immediately adjacent pixel pairs to the left and to the right in the selected region; and

determining an angle corresponding to the first valley pixel pair as the substantial angle.

31. The display image enhancement method of claim 30, wherein the step of determining the substantial angle further includes the steps of:

comparing the filtered differential value of the first valley pixel pair and the filtered differential value of the pixel pair representing a 90° correlation; and

outputting 90° as the substantial angle if the filtered differential value of the first valley pixel pair is greater than or substantially the same as the filtered differential value of the pixel pair representing the 90° correlation, and otherwise outputting the angle corresponding to the first valley pixel pair as the substantial angle.